

## EXHIBITION OF PHYSICAL APPARATUS.

THE third annual exhibition of physical apparatus, held under the auspices of the Physical Society of London at the Royal College of Science on December 13, was an unqualified success. Notwithstanding the inclemency of the weather there was a good attendance, many members of the society coming up from distant towns in order to take advantage of the opportunity of inspecting the apparatus itself in lieu of looking through the catalogues of so many makers. Printed and verbal information was available in abundance, and in connection with the former it may not be out of place to offer a word of advice to makers. Any catalogue, however carefully compiled, is in the case of a progressive maker out of date a few months after publication, and is generally supplemented by separate sheets sent out to customers. Very few makers have these sheets cut the same size as their catalogues, and fewer still provide clips at the ends of their catalogues by means of which the additional sheets, sent out punched in the left-hand margin, can be permanently incorporated in the catalogue. They lie about on desks instead until they look dusty and disreputable, and are then consigned to the waste-paper basket, and the information contained in them is forgotten.

As one would naturally expect, the exhibition was strongest on the electrical side, but other branches were not neglected. In general physics, the silica ware exhibited by Messrs. J. J. Griffin and Sons attracted a considerable amount of attention. Bowls of 6 inches diameter, boiling flasks of 3 inches, and tubes of all kinds can now be made of transparent silica, while much larger objects are made of the opaque variety.

Messrs. C. F. Casella and Co. exhibited a telemeter with an 8-foot base, arranged to measure both distances and differences of level, the telescopes rotating about the base and the base about a vertical axis through its centre to eliminate errors. They showed also a direct-reading anemometer on which the revolutions are given by an ordinary engine counter. Messrs. Elliott Bros. exhibited their new "motometer," or speed indicator, for motor-cars, which is driven from a flat rubber ring attached to the front off-side wheel of the car by means of a friction wheel and flexible shaft.

In heat, the most interesting exhibit was that of the Meteorological Office, which consisted of balloon and kite meteorographs and traces obtained by means of them. Mr. Dines's instrument for recording pressure and temperature on a square inch of thin copper weighs one ounce only, and is most ingenious. Records of ascents of 18 to 20 kilometres, made at the same time at four stations in this country, showed a fair agreement in the temperatures at the same heights over the four stations at comparatively low levels, but considerable differences at high levels.

In photometry there appeared to be a general adoption of the flicker photometer and of the inclined screen method of varying the effect of one of the sources. The movement of the screen is effected by means of a cam rotated by a milled head outside the photometer box, to which a pointer reading on a scale marked directly in candle-power is attached. The uniformity of the divisions is secured by the shape of the cam.

Messrs. A. Hilger, Ltd., exhibited a large spectroscope the telescope of which was moved by a tangent screw graduated on the head directly in wave-lengths. They also had on view a Fabry and Perot interferometer with the interference bands visible, so that the displacement produced by separating the plates could be observed.

Two new photographic lenses giving very flat fields were exhibited, the "Isostigmat" by Messrs. R. and J. Beck, and the "Homocentric" by Messrs. Ross, Ltd.

The work on radio-activity, which is being carried on so vigorously, has raised the electroscope to a position undreamed of a dozen years ago, and amongst the many new forms it now takes may be mentioned one constructed by Mr. C. W. Cook, of Manchester, for Prof. Rutherford, and exhibited by Messrs. J. J. Griffin. It contains a compartment below the leaves in which the radio-active material to be investigated can be placed.

Resistance bridges for the most accurate work appear to be tending towards the enclosed type, with oil circulation

to ensure uniformity of temperature. The Cambridge Scientific Instrument Co. showed a Callendar and Griffiths bridge in which plug contacts were replaced by mercury, also enclosed, to prevent the mercury getting to the brass-work.

Several makers seem to be alive to the possibilities of the flat form of resistance coil owing to its compactness and freedom from inductance and capacity. Mr. L. Miller's machine for winding the wire of induction coils in flat vertical sections, the wire passing from outside to inside and back again without a break throughout the whole length of the coil, seems to make it possible to build larger coils without insulation troubles arising. His mica-disc valve, which interposes a disc of mica in a short air gap in the secondary circuit of the coil during the make, and so cuts down the make current that the secondary current is practically unidirectional, should prove a great aid in vacuum-tube work.

Moving magnet galvanometers show a tendency to take the Broca form, in which astaticism is secured by making the poles between the coils consequent poles at the centres of two magnets placed vertically. Instruments so constructed were shown by the Cambridge Scientific Instrument Co. and by Messrs. Clark Fisher and Wadsworth. A very useful addition to the moving coil type of galvanometer was exhibited by Messrs. Gambrell Bros. It consists of a resistance within the galvanometer case, which when placed across the terminals of the instrument renders it aperiodic. One end of it is connected to one terminal of the instrument, and the other to a third terminal, so that it may also be used to diminish the sensitiveness of the galvanometer.

Messrs. Paul exhibited a Campbell vibration galvanometer, which is a moving coil instrument of very short period, the control being of the bifilar type, and the amplitude of the oscillations being observed in working with the instrument. Other instruments for small alternating currents were Duddell's thermo-ammeter, on the same principle as his thermo-galvanometer, shown by the Cambridge Scientific Instrument Co., and Cohen's barretter, shown by Mr. R. W. Paul. This instrument is of the bolometer type, the filaments the resistances of which are changed by the current to be measured being those of the 24-volt lamps used on telephone switchboards.

Of instruments intended for commercial work, the iron-clad indicating wattmeter shown by Messrs. Nalder and Thompson may be mentioned, as it illustrates the present tendency to secure larger torques by placing the moving coil in the field of a laminated series or shunt electromagnet.

Messrs. Nalder Bros. exhibited a compact testing set weighing only 14 lb., capable of measuring insulations up to 2000 megohms with 100 volts, and Messrs. Evershed and Vignoles several of their "meggers" of various ranges up to 1000 megohms.

The Physical Society is to be congratulated on the success of its exhibition, and the various exhibitors on the interest which their display evoked.

C. H. L.

ON THE INCIDENCE OF DAYLIGHT AS A DETERMINING FACTOR IN BIRD-MIGRATION.<sup>1</sup>

THE existence of the phenomenon of bird migration is only explicable, like that of all other phenomena of life in both animal and vegetable kingdoms, by the theory of natural selection. It has proved beneficial to certain families of birds in the struggle for existence to wander at certain times of the year in particular directions, and to greater or less distances, such wanderings having led them to regions which were more suitable than others for feeding or breeding. On this general question there can be no difference of opinion at the present day.

But if we leave the general problem and come to deal with specific parts of it, such as the nature of the directing force in migration, or why for certain birds northern latitudes are more suitable as breeding quarters than southern, why for others eastern longitudes than western, we at once enter upon questions regarding which there is

<sup>1</sup> Address to the Scottish Natural History Society, November 7, by Prof. E. A. Schäfer, F.R.S.

great divergence of opinion, and as to which scarcely any two naturalists who have studied the subject are in complete agreement.

The part of the problem that I propose here to consider can be thus stated:—Is there any physiological reason to account for the fact that for that class of birds which we may call the north-south migrants northern latitudes have determined themselves as the most suitable for summer quarters and breeding grounds, and southern latitudes for winter quarters?<sup>1</sup>

The physiological reason for this choice of quarters which most naturally suggests itself concerns the presence or absence of food, or its relative abundance and the means of procuring it. From the Arctic circle, where during winter the whole of nature, sea and land alike, is in the grip of an intensity of cold of which we can form little conception, and which few animals can withstand, birds, at any rate, must move southward, or they would inevitably perish of cold and starvation. It thus appears easy to account for one aspect of the north-south migration problem by referring it to the necessity of avoiding destruction by starvation; but even for this aspect of the question the answer is not quite so simple as at first sight appears. For it fails to account for the distances which such migrations often take, since a passage into the north temperate region alone would suffice to obviate this difficulty; yet this region is, for the most part, passed in the migration of many Arctic birds, which may not stop until a tropical or even a southern hemisphere region is attained; and not only so, but the north-south migrants of the north temperate zone themselves share in the migration, passing away for the winter to a southerly clime. Many of these cannot be said to be driven south by the lack of food, for at the time the migration occurs food is usually still abundant, and there is plenty of food during the whole winter in many of the countries which are passed to support, not only the permanent avine inhabitants, but in some regions myriads of east-west migrants besides.

Moreover, there is evidence that during the Tertiary period the climate of the Arctic circle was entirely different from that which now exists—warm and mild, and abounding with vegetable and animal life—and there was then no necessity for north-south migration on the score of want of food materials. Yet it is impossible not to suppose but that migrations occurred then as now, since the habit of migration is so ineradicably engrained in the nature of the bird that it is difficult to believe that it was not evolved along with the development of the organs of flight.

If we now turn to the other aspect of the north-south migration problem and consider the causation of the movement from south to north, we see that the explanation *re* food supply, which seems easy to formulate for the north to south movement, at once breaks down, for the tropical and temperate regions are at any rate not less abundantly provided with food during summer than the regions of the far north to which the majority of these migrants wend their way. The difficulty is a serious one. The explanation which was used to account for the north to south movement is not available for the opposite movement; some other explanation must be found. Here the weakness of the original explanation manifests itself, for it would be natural to suppose that the reversal of an effect would be the result of the reversal of the cause which produced the effect, and this is not the case in the present instance.

What, then, are alleged to be the reasons for the south to north migration in the spring? One of these supposed reasons is both given and at the same time refuted by Gätke ("Birds of Heligoland," English translation, p. 144) in the following passage:—"From very old times, mainly in consequence of the phenomena which succeeded migration, it was conceived that in spring, with re-awakening life in Nature generally, the reproductive instinct of birds also was roused afresh, and that it was this which urged them to wander to their nesting places; while in autumn, dearth of food and cold admonished them to make a temporary home in warmer latitudes. This view has, in part, held its ground up to recent times, for it is not so long ago that Brehm, in one of his talented discourses

on this inexhaustible theme, maintained that the two great factors in the world's action, *Hunger* and *Love*, also dominated the migratory movements of birds. . . . These explanations, however, do not suffice . . . it cannot be the reproductive instinct which prompts birds to set out on their spring migration, for many species do not breed in the first, second, or even third year of their life, and yet migrate to their homes just like those of their congeners who are endowed with the capacity of breeding; nor are they induced to travel by the example of their parents, for they start on their journey alone, and independently." Gätke concludes as follows:—"In regard to this question as to the immediate cause of the departure of birds in their migration . . . we are confronted with a riddle which has hitherto defied every attempt at a solution, and which indeed we may hardly expect will ever be likely to receive a final explanation."

We may take it, then, that the hypothesis that the commencing recrudescence of the generative functions in spring is the determining agent for the migration from south to north does not furnish an adequate explanation of the phenomenon, even if it were certain, as is by no means the case, that such recrudescence begins before the commencement of the movement. It seems obvious that there must be something in the higher latitudes which is favourable to breeding or to the rearing of offspring. Are we to suppose this favourable factor to be relative coldness? *Prima facie* this seems improbable. Other animals, including non-migrant tropical birds, breed freely in the hottest regions of the earth's surface, and warmth is favourable for incubation. Many of the east-west migrants have their breeding grounds in the interior of the great Asia-European continent, which is in the summer much warmer than its western shores. I have been unable to come across any fact which would lead one to suppose that mere diminution of temperature assists breeding. There are, it is true, some fishes and possibly a few other animals that produce their eggs and young in the winter, but in by far the majority it is the warmer season of the year which is occupied with the propagation of the race. We are therefore forced to conclude that the south to north migration is not brought about because of the necessity or advantage of a colder climate for breeding and nesting. Is there, then, any other means of explaining why it is advantageous for certain birds to pass the summer, and especially to breed, in high latitudes, which will equally account for the fact that lower latitudes present corresponding advantages during the winter season? It is an answer to this question that I will now attempt to give.

Let us begin by admitting that bird-migration must have been brought about by the necessity for procuring a sufficient supply of food. The importance of this at all periods is self-evident, but it becomes accentuated in the breeding season, when not only the needs of the parent birds, but also those of their voracious offspring, have to be met. It appears to have been assumed by most writers that for the north-south migrants the higher latitude or summer region of distribution, to which they resort for the breeding season, represents their original home or habitat, to which it is only natural they should desire to return when the desire for breeding comes upon them, and that the migration to lower latitudes is brought about by climatic conditions, such as frost and cold, which render the procuring of food a matter of difficulty or impossibility during winter. There are, however, as has already been pointed out, difficulties in accepting the climatic conditions and accompanying deprivation of food supply as affording the only or even the chief explanation of migration, and more especially of the acquisition by birds of the north-south migratory habit. Thus it fails, as we have seen, to explain the south to north migration in the spring, and would be an inadequate reason for much of the autumnal migration which occurs from the northern temperate zone, such as that of those migratory marine birds the food of which is abundant in the northern seas throughout the winter. It at first sight appears also to fail to account for the fact that with many species of birds autumnal migration occurs before the advent of severe weather and at a time when the food supply in the higher latitude is as abundant as ever, and that their

<sup>1</sup> For convenience of description the migrants are here assumed to belong to the northern hemisphere.

return from lower latitudes often takes place when the food supply there is more abundant than in the higher latitude to which they are travelling, and may even remain abundant. But although a deficiency of food could not in such circumstances be the immediate determining cause of the movement, an approaching deficiency might, nevertheless, be the ultimate cause, for the most appropriate time for leaving a region which is to become uninhabitable would be determined for each species by natural selection, and might thus appear to have no immediate connection with deficiency of the food supply, although in reality dependent upon it.

It is known, however, that, as has already been stated, during the whole Tertiary period there was a mild or warm climate and abundant vegetation throughout what are now the Arctic and sub-Arctic regions, and it was under these conditions, which presuppose abundance of food supply during the whole winter, even in the highest latitudes, that many existing genera of birds were evolved. We may take it, therefore, that at that period the autumnal migration was not rendered necessary by the approaching severity of the winter months.

This being the case, the question has suggested itself whether the relation of daylight to darkness may not have furnished the factor of most importance in the determination of both the south to north and north to south movements, *in consequence of the necessity to most birds of daylight for the procuring of food.*

In no other class of vertebrate animals is the sense of sight more important than in birds, and in no other is it so highly developed. For detecting and obtaining food most birds depend entirely upon vision, with perhaps, in some, assistance from audition, and, in the case of soft-billed birds, from palpation, but with little or no aid from the olfactory sense, which is in so many animals the most important of the senses in this connection. But vision is not possible in the total absence of light, nor, without special retinal adaptation, in semi-darkness. Hence the great majority of birds—diurnal birds—are dependent upon daylight for the procuring of food; relatively few, such as most owls and nightjars (crepuscular and nocturnal birds), are able to obtain food only in semi-darkness (twilight, moonlight, or starlight); a certain number, e.g. many waders, appear to possess retinal adaptation both for ordinary light and for light of low intensity; but, so far as I am aware, no birds, except those which are provided with tactile bills, are able to seek food in total darkness.

From this consideration it is obvious that the proportion of the twenty-four-hour cycle which can be utilised by birds for obtaining food becomes greatly diminished during the winter months in high latitudes, and may be reduced to *nil* within the Arctic circle, while during the summer months the amount of daylight in high latitudes is proportionately increased. Many birds are voracious feeders, and during the hours of daylight are almost constantly engaged in the search for food. It is therefore a necessity that the time during which alone they can see to engage in the search shall not be unduly restricted, as would be the case in high latitudes during the winter, even in parts which are rarely or never frost-bound. This the north to south or autumnal migration provides against. During the breeding season, when the young birds also have to be fed, it is important that the time which can be occupied in the search for food should be prolonged, and this is provided by the south to north migration in the spring. Everyone who has lived in northern latitudes must have been struck with the time occupied by many birds during the long summer days in procuring food for themselves and their young; in fact, no more striking object-lesson of the utility of prolonged daylight for the rearing of their offspring can well be afforded.

The objection might be taken to the relative incidence of daylight and darkness at different seasons being regarded as a factor in causing north-south migration, that in the case of nocturnal birds the course of migration ought to be the other way, viz. from south to north in autumn and from north to south in spring (in the northern hemisphere); but as has been already pointed out, the so-called nocturnal birds are not, as is popularly supposed, birds which can see in the dark, but birds the vision of which is adapted permanently for light of low intensity,

such as twilight. Migration with such birds occurs in the same sense as with diurnal birds, i.e. north to south in autumn and south to north in spring (in the northern hemisphere). This is, in fact, what might have been anticipated, seeing how greatly the summer twilights are prolonged in high latitudes.

Again, it might be objected that the circumstance of many birds leaving the higher or lower latitudes before the autumnal or vernal equinox militates against the assumption that the autumnal migration is determined by a relative deficiency of light in higher latitudes during the winter months, and that the vernal migration is determined by the longer daylight which obtains in those latitudes during the summer months. This objection is, however, obviously met in the same manner as with the analogous objection raised to the "food-supply" theory pure and simple, viz. that the most appropriate time for the actual commencement of migration will have been determined for each species by the process of natural selection.

Further, the assumption that the relation of light to darkness rather than severity of climatic conditions has been the determining factor in producing the north-south migrations would better explain the singular constancy in the times of year at which these migrations occur. For not only are the times of migration in many cases independent of the actual climatic conditions which are supposed to be the determining cause of the movement, but the climatic conditions themselves vary considerably from year to year in their inception and progress. On the other hand, the incidence of the proportion of light to darkness is a constant factor, and might even be conceived to be operative in exciting the migratory instinct into activity in the same manner as it is here assumed to have been the original determining cause of north-south migration. That there are other stimuli seems probable from the circumstance that some birds have their winter quarters in the equatorial region, where the proportion of day to night does not vary throughout the year. There are, however, very regular seasonal changes in that region, which are accompanied by marked differences in amount of daylight, and for those migrants which winter there these seasonal changes may serve as the initiating stimulus to northerly migration. That it is a result of developmental changes in the sexual organs is improbable, since sexually immature individuals are also subject to the migratory tendency; nor is there any evidence that such changes begin prior to migration. In any case, the regularity with which migration occurs indicates that the exciting cause must be regular. There is no yearly change, outside the equatorial zone, that occurs so regularly in point of time as the change in the duration of daylight. On this ground this may well be considered a possible determining factor in migration, and it has the advantage over other suggested factors that it applies to the northerly as well as to the southerly movement.

Besides the north-south migrations with which we are more immediately concerned, there are also the great east-west vernal and autumnal movements which are so prominent a feature in the eastern parts of these islands, and also migrations of a more local character, both of which merit some allusion in connection with the general question of migration.

As regards the east-west movements, which are, in fact, for many species a part of the general north-south migrations,<sup>1</sup> it has been supposed that these divarications from the main north-south stream have become evolved either as the result of changes in the earth's surface, which have produced a modification of the general north-south trend,<sup>2</sup> or that they are the expression of the course of expansion of the breeding range of the species as it approaches its northern limit.<sup>3</sup> The physiological reason for the east-west movement must ultimately be sought, as in the north-south movement, in facility for the obtaining of food, and it may fairly be assumed that in the case

<sup>1</sup> For the evidence of this see Gätke, "Heligoland an Ornithological Observatory," pp. 39-43. Also the British Association reports on bird migration, especially the "Digest," by W. Eagle Clarke, in report of Liverpool meeting, 1896.

<sup>2</sup> Evans, *Cambridge Natural History*, "Birds," p. 18.

<sup>3</sup> Dixon, "The Migration of Birds," 1897, p. 35; also p. 40.

of species which show no north-south tendency in migration and which are confined to the temperate zones there is sufficient opportunity, even in shortened days, of obtaining such food as they require for subsistence in the region to which they have betaken themselves for winter quarters. Many of these east-west migrants are either graminivorous or live on insects and grubs which they seek in the ground or on trees. In the summer their food is most abundant in the great grain-producing or forest-clad central regions of the Asia-European continent, while in the winter they are compelled to seek their subsistence in a less severe climate.

Another kind of migration is that which may be produced by local conditions of food and pressure of bird population. If in any particular zone food of appropriate character is obtainable at all times of the year in sufficient abundance, the necessity of migration to a higher or lower latitude is no longer necessary for a specific number of individuals, and their migration, and that of their descendants, will accordingly tend to limit itself to that zone, within which such migration as does occur will be more or less local.

Newton<sup>1</sup> suggested that the arrival of a large batch of migrants in a particular area or zone which is already occupied by birds of the same species may compel the individuals of that species which are in possession to move on in any direction where food is readily obtainable. It is perhaps more probable that later migrants into a zone already occupied by birds of the same species or habits may, on finding others already in possession, themselves push on into other regions. In this case the later migrants of species which vary in the extent of their migration would tend also to become the more extensive migrants, and would by natural selection transmit this tendency to their descendants. This conforms to the statement that those individuals of a species which migrate to the higher latitudes in the range of distribution of the species start their spring migration later than the individuals which migrate to less high latitudes.<sup>2</sup>

The theory that bird migration in the Holarctic area was originally determined by the encroachment and subsequent retreat of the ice-sheet over the temperate zone during the Glacial epoch (or epochs) is one which appears impossible to accept. Such a theory in its bare form involves the assumption that the habit of migration which so extensively pervades the avine class of vertebrates has been acquired during comparatively recent geological times, for which there is neither evidence nor probability. When we consider how extensively diffused is the tendency to migration of some kind amongst birds, it appears reasonable to assume that the habit was acquired at a comparatively early period of their evolutionary history. It may even be that the advantage gained by a more and more extensive movement of the kind was the predetermining cause, in the hands of natural selection, of the complete evolution of the avine type of vertebrate.

I have been able to find in the literature only two references dealing directly with the subject of the influence of light on bird migration. Seebohm ("The Geographical Distribution of the Family Charadriidæ," London, 1888, p. 34) writes as follows:—"The first migrations of the ancestors of the Charadriidæ were probably not in search of warmth, for the climate of the Polar Basin was in those remote ages mild enough: nor in search of food, which was probably abundant all the year round; but in search of light during the two or three months when the sun never rose above the horizon. The habit of migration thus formed became deeply rooted in the species, in accordance with the law of heredity: and doubtless acquired additional force when the terrors of a glacial epoch exterminated the conservative party amongst the Charadriidæ (if any of them were foolish enough to neglect to adapt themselves to the changed circumstances), and compelled the survivors to extend their migrations far

and wide, until the shores of nearly all the rest of the world were visited on passage, or included in the winter range of some species of the family."

Seebohm evidently realised that, however warm the circumpolar area and however well stocked with food, it would be impossible for birds to subsist there all the year round on account of the absence of daylight during the winter months. It is the more strange that he should have failed to perceive the obvious corollary that these birds might seek such high latitudes during the summer months in the breeding season on account of the advantage offered for the procuring of food by the prolonged daylight.

Some fourteen years prior to the publication of Seebohm's work there appeared in the *Academy* (1874, vol. vi., p. 262), under the head of "Notes and News," the following paragraph,<sup>1</sup> which, however, bears no indication of the source whence the information it contains was derived:—

"The aged poet Runeberg, the greatest scald that Sweden has ever had, has been in extremely weak health for many years past. It appears that as he has lain on his sick bed, at Helsingfors in Finland, he has occupied himself by close observation of the habits of birds, and specially with regard to the causes of migration, and he has at last put forward a singularly beautiful theory on the latter point. He believes, in fact, that it is the longing after light, and that alone, that draws the birds southwards. When the days shorten in the north, the birds go south, but as soon as ever the long northern nights (*sic*) set in, with all their luminous and long-drawn hours, the wanderers return to their old haunts. It is generally supposed that they move southward to get more abundant food; but why, asks Runeberg, do they leave their rich hunting-grounds to return to the north? The central regions of Europe are in every way more desirable than the wastes of Scandinavia. Only one thing is richer there, and that is light. The same instinct that makes plants firmly rooted in the ground strain towards the light, spreading upwards in search of it, works in the birds, who, on their free wings, fly after and follow it. This very suggestive and poetical notion is further carried out by reference to various analogies in natural history, and the final sentence is quite epigrammatic: 'The bird of passage is of noble birth; he bears a motto, and his motto is *Lux mea dux*.'"

The idea which is given voice to in the above paragraph bears a certain resemblance to that which I have endeavoured to set forth in this paper, but on close consideration it will be seen that the resemblance is purely superficial. What I have tried to urge is, not that these north-south migrants seek light *quâ* light, but that the sense by which alone they are for the most part able to obtain food necessitates their passage to regions where at one or another time of year there will be sufficient daylight to procure it. This is a special part of the general problem of food supply, itself an all-important agency in natural selection, which last there can be no doubt has been instrumental in determining the habit of migration. The theory attributed to Runeberg, in so far as it seeks to explain north-south migration by the endeavour of the bird to follow light alone without reference to the ultimate reason for such movement, in no way explains why birds rather than other animals should require light, and may well have merited the criticism to which it was at the time subjected by Prof. Newton (*NATURE*, September 24, 1874, p. 415), who pointed out that since "the southern movement not only begins but is with many species in great part accomplished long before the autumnal equinox, when consequently the birds are journeying to increasingly shorter days; and in like manner their northward movement is set on foot before the vernal equinox," the theory (that it is light alone that is the attraction) "contains its own refutation."

The object of this paper has been to endeavour to give a reasonable explanation of the north-south tendency, which is the most prominent feature of bird-migration. No attempt is made to explain all phenomena of migration. Obviously there are some migrations which cannot be explained on the assumption that the object of move-

<sup>1</sup> The paragraph was copied in the *Times* for September 18, 1874.

<sup>1</sup> "Dictionary of Birds," art. Migration.

<sup>2</sup> This appears to be the case with the swallow (see W. Eagle Clarke, British Association Report, 1901, p. 10), the individuals which are to summer in Scandinavia passing through this country after our own swallows have arrived. Similarly, the return of the Scandinavian swallows also appears to be somewhat later than ours (middle of September, p. 12). (See also the same author's "Digest," British Association Report, 1896, p. 17).

ment is to obtain more extended daylight. This, however, is not to be wondered at, since the quest of daylight is itself only a part of the greater problem of food supply. Any condition, local or other, which tends to restrict food supply in a particular area must produce migration from that area into more favoured areas. This is alone sufficient to account for the winter migrations which many birds exhibit, sometimes to a large extent, and for the localised migrations which some species, not usually regarded as migrants, exhibit in spring and autumn, moving from one area into another, not necessarily in a different latitude, although often of a different altitude. Further, it must be borne in mind that some birds, and those not few in number, find both sufficient food and sufficient daylight to acquire it in the same region all the year round, and exhibit no tendency to migrate. This can in no way be employed as an objection to the view that the true north-south migrants have been driven to seek more extended daylight for the purposes of obtaining a sufficiency of food; it would equally apply to any other explanation that might be given to account for the migratory tendency, and could only be used to prove that there is no necessity for any migration at all, which, as Euclid would say, is absurd. Given a food supply adequate in nature and amount to maintain the species in any region, and sufficient light all the year round to procure it, there would be no need for migration.

But these are not, and never have been, conditions which obtain in all regions and for all species. On the contrary, a very large number of species appear to require the prolonged daylight of the northern summer to procure a sufficiency of food for themselves and their offspring, while, apart from severity of climate, the shortened hours or absence of daylight which supervene there necessitate that they should pass the winter months in southern latitudes. Thus we can comprehend how the north-south migratory instinct became evolved, and we no longer wonder at the existence of this phase of the phenomenon. That the great east-west migrations are more complex and more difficult of explanation I am free to admit, but it must not be forgotten that we know, on the whole, less about these, and especially less about the climatic and other conditions which accompany them and may be supposed to produce or influence them, than we do about the influences to which the north-south migrants are exposed. The fact that we are not in a position to solve the whole of a complicated problem need not prevent our attempting to deal with any part for which our existing knowledge enables us to devise an explanation. If I have approached the question entirely from a physiological aspect, it is because it is in the main a physiological question. Nevertheless, no physiologist has hitherto attempted to deal with the subject, and it is only with diffidence that I encroach upon a domain which the morphologist has up to the present regarded as his own.

#### CRETAN EXPLORATION.

AN appeal is made by Dr. Arthur J. Evans, F.R.S., for funds to complete the excavation of the "Palace of Minos," which has now been carried on for seven years. At the beginning of the present year it was thought that supplementary explorations on a comparatively small scale would be sufficient, and that by the close of the season something like finality might be attained as regards at least the palace site of Knossos. This forecast, however, was by no means borne out by the result. The season's work, which was intended to be of a more or less supplementary nature, broadened out into a somewhat extensive excavation, the result of which is to show that another great campaign must be carried through before the excavation of the palace site at Knossos approaches completion. It is estimated that at least another 3000*l.* is required to complete the work, and this must be met by public subscription, for, as Dr. Evans points out, in this matter it is unfortunately impossible for an English explorer to rely, like his French, German, and Italian colleagues, on Government grants or large subventions from national academies. Writing in support of the appeal in the *Times* of November 21, Prof. C. Waldstein, referring to Cretan exploration as a scien-

tific labour which has brought credit to the British nation all over the world, says:—"In any other European country the Government would have subsidised, if not paid, all the expenses of what can in no way be considered a private enterprise. . . . Does not a wider public take some interest in the higher research carried on by the scientific representatives of the nation, and can the wealthier classes in England not be brought to give material support to the efforts of those who thus stand for the nation's higher culture? Is it impossible to hope for a Government subsidy? If it be not the 'tradition,' good traditions can be inaugurated by those who lead the nation. No amount of immediate effort to raise our industries by direct technical education will prepare us to cope with the competition of the other leading nations of the world. We must raise the tone of intellectuality by arousing the national interest in the highest forms of intellectual life." Subscriptions for the Cretan Exploration Fund can be sent either to Mr. G. A. Macmillan, St. Martin's Street, W.C., or to Messrs. Robarts, Lubbock, and Co., Lombard Street.

#### A LUNAR "NEW JERUSALEM."

A PAMPHLET has been received containing a series of lectures by the Rev. G. B. Berry on "The New Jerusalem," with a preface by the Lord Bishop of Exeter. With the spiritual interpretation of the Apocalypse we are not concerned in these columns, but an astonishing speculation put forward in the last lecture demands a word of comment. Mr. Berry suggests that the invisible part of the moon has the same size and shape as the mighty pyramid which, according to Revelation, forms the heavenly Jerusalem. Eventually the lunar hemisphere visible to us is to bury itself in the earth, and the pyramidal portion is to project above "the rack and ruin of the elements" caused by the catastrophe, and to be the Celestial City in which the faithful will pass eternity. As a vision, this picture may appeal to imaginative minds, but from the point of view of celestial mechanics it can scarcely be taken seriously. A pyramid of the dimensions of that upon which Mr. Berry's New Jerusalem rises tier upon tier would be crushed by its own weight even if it were built of steel. As, however, the structure is visionary, we imagine that this material fact affords no valid objection to it. The changed moment of inertia of a moon with the invisible side of a pyramidal form would necessitate modification of the whole theory of the physical librations of our satellite; but perhaps Mr. Berry does not appreciate the force of this difficulty. He is certainly not familiar with the theory of tidal friction or with the fact that Laplace, who studied the physical librations, showed that one side of the moon always faces the earth because that position is one of dynamical stability. A fuller knowledge of celestial mechanics might have made Mr. Berry hesitate before erecting such a visionary structure as he describes upon so slender a foundation. His views would have pleased mediæval schoolmen, but modern science demands that even the most fascinating hypothesis should be based upon results of observation capable of being put to the test of inquiry rather than upon "revealed truth" to be accepted without criticism.

#### UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

THE governing body of the South-Western Polytechnic has appointed Dr. Louis Lownds head of the department of physics. Dr. Lownds is the author of papers on the thermoelectric and thermomagnetic properties of bismuth crystals and on other subjects. Dr. W. H. Eccles, formerly head of the joint mathematical and physical department, has been made head of the department of mathematics.

THE annual distribution of prizes and certificates at the Borough Polytechnic Institute was held on Thursday, December 12, when Sir Edward Carson, K.C., M.P., presented the prizes and delivered an address. Mr. Spicer, the chairman of the governing body of the institute, in the course of his remarks referred to the building extension